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CHART
Swiss Accelerator Research and Technology

HFM
High Field Magnets

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Stress-Managed Asymmetric Common-Coils (SMACC)

6th Common-Coils Joint Meeting – May 2024

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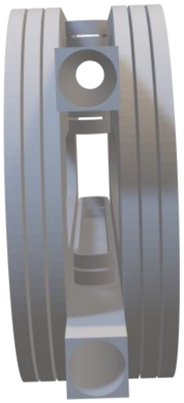
This work was performed under the auspices and with support from the Swiss Accelerator Research and Technology (CHART) program

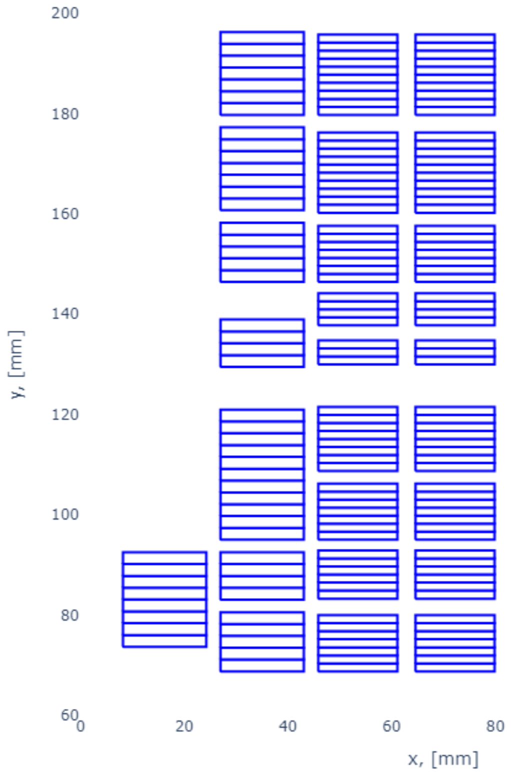
Motivation

In respect to standard common-coils magnet, we would like to:

- deal with high Lorentz forces in a different way
- simplify the common-coils architecture for accelerator magnets
- have a full common coils architecture and reacting & winding



Stress-Managed Asymmetric Common-Coils (SMACC) –Nb_3Sn – hf_3



1 2 3 4

Layers	1	2	3	4
Wire type	Nb_3Sn RRP® 162/169	Nb_3Sn RRP® 162/169	Nb_3Sn RRP® 78/91	Nb_3Sn RRP® 60/91
N wire x dia in mm	26 x 1.1	26 x 1.1	40 x 0.7	40 x 0.7
Cu/nCu	0.9	0.9	1.2	1.8
Bare Cable dimensions in mm*	15.77 x 2.06	15.77 x 2.06	14.94 x 1.3	14.94 x 1.3
Insulation thickness in mm	0.155	0.155	0.155	0.155
Number of turns	8	43	62	62

* Does not include Rutherford cable core

Stress-Managed Asymmetric Common-Coils (SMACC) – Nb_3Sn – hf_3

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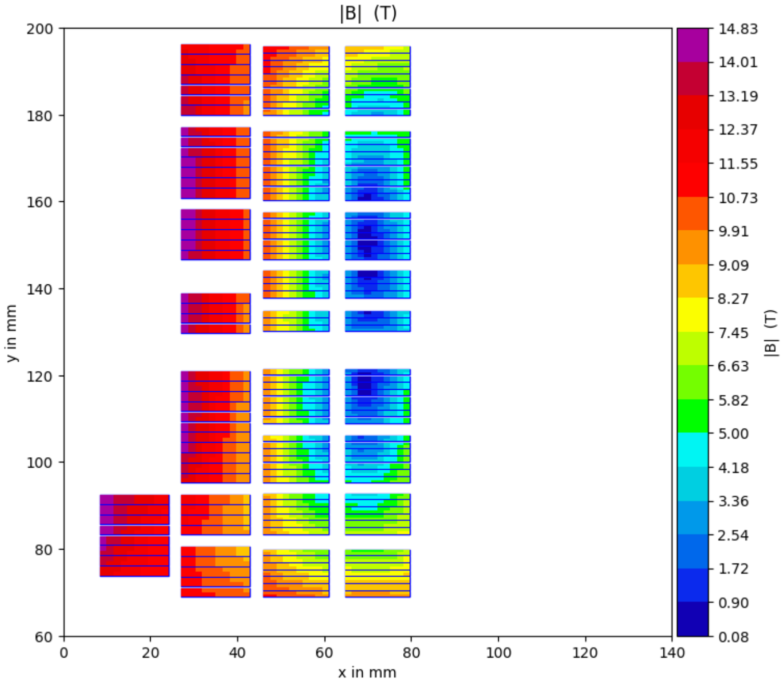
1 2 3 4

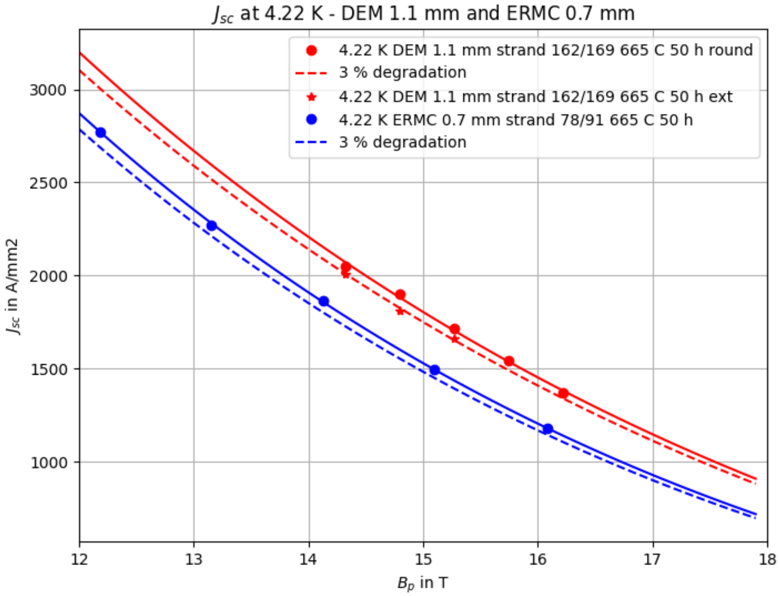


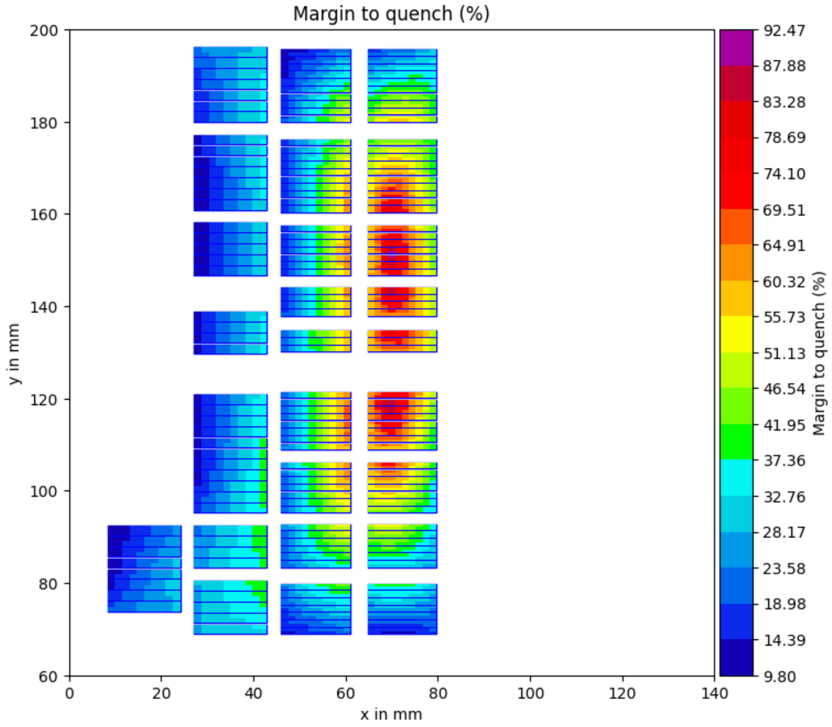
B_0 in T	E_{op} in MJ/m	T_{op} in K	% Margin	I_{op} in kA
14	2.94	4.22	9.8	14.77

<table>
<tr><th>Layer</th><th>B_{peak} in T</th><th>% Margin</th><th>J_{sc} in A/mm²</th><th>J_{cu} in A/mm²</th><th>J_{ov} * in A/mm²</th></tr>
<tr><td>1</td><td>14.83</td><td>9.80</td><td rowspan="2">1135.8</td><td rowspan="2">1261.2</td><td rowspan="2">389.5</td></tr>
<tr><td>2</td><td>14.81</td><td>9.91</td></tr>
<tr><td>3</td><td>11.24</td><td>11.68</td><td>2110.8</td><td>1759.0</td><td rowspan="2">605.7</td></tr>
<tr><td>4</td><td>9.78</td><td>13.98</td><td>2686.5</td><td>1492.5</td></tr>
</table>

* Including insulation area

Stress-Managed Asymmetric Common-Coils (SMACC) – Nb_3Sn – hf_3 - 14 T





High-Field (1 and 2) and **Low-Field (3 and 4)** Jc fitting

The same Jc fitting is used for ERMC and DEM-0.7

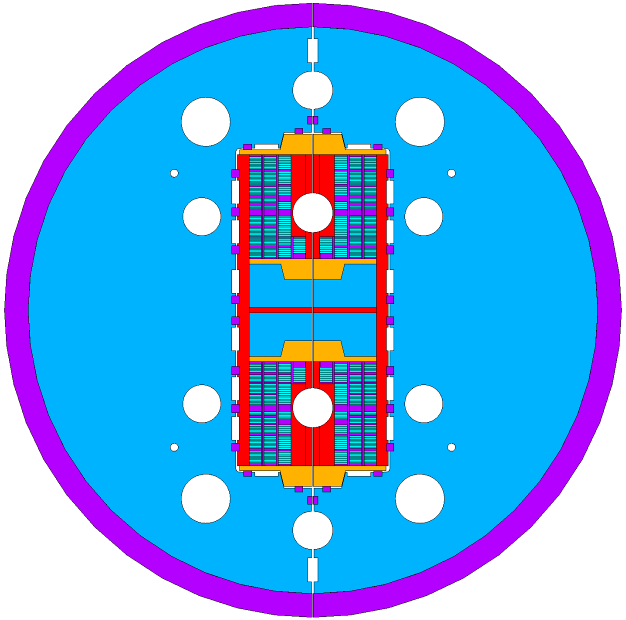
Stress-Managed Asymmetric Common-Coils (SMACC) - Cross-Section

The asymmetric common-coils magnet has an intra-beam distance of 250 mm, 50 mm **bore**, **yoke** diameter of 660 mm and 30 mm thick stainless-steel **shell.**

The magnet has 4 different types of coils (layer 1, layer 2, layer 3 and 4) and 8 coils in total (for a double aperture magnet). The coils are placed in the stress-management **formers**. The preload is transferred towards the inner-most layers through the **ribs**.

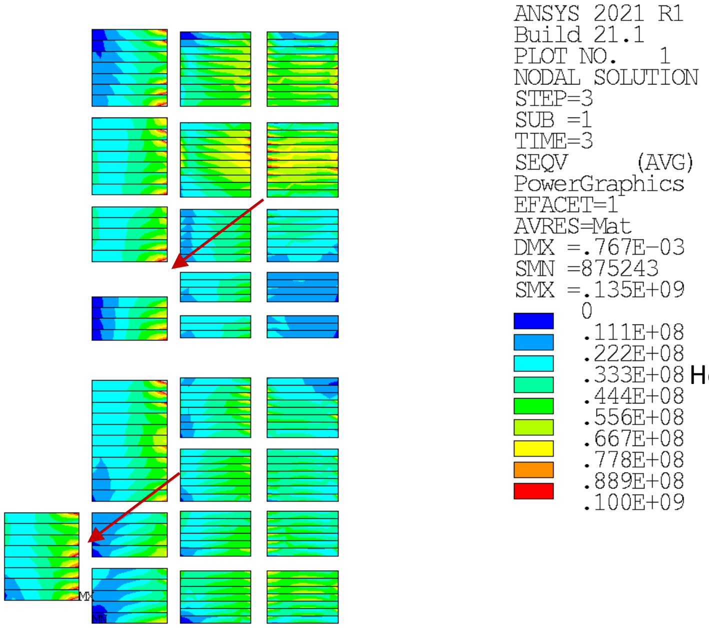
The **iron pole,** combined with the asymmetric concept, helps on the balance vertical force balance.

The magnet concept is based on bladder & keys technology for room temperature preload.

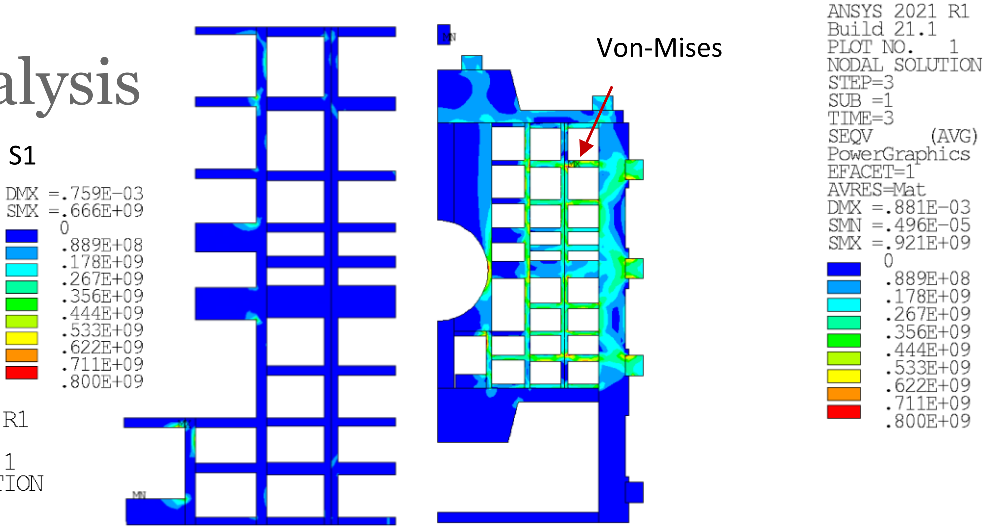


Mechanical Analysis

Von-Mises

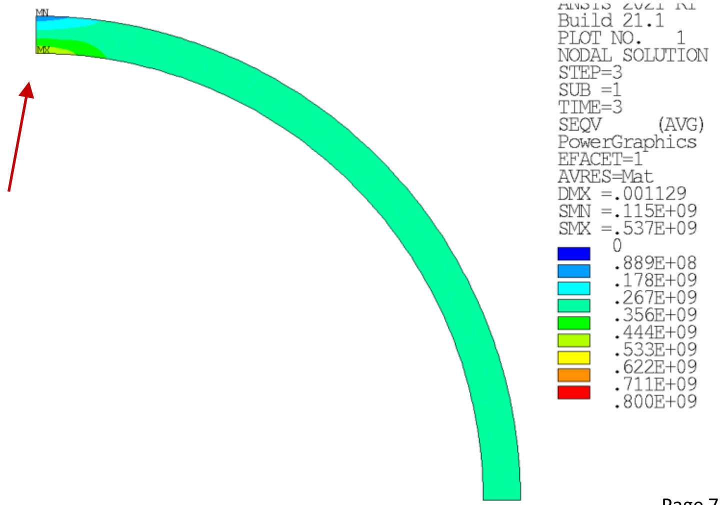


Nominal field



Nominal field

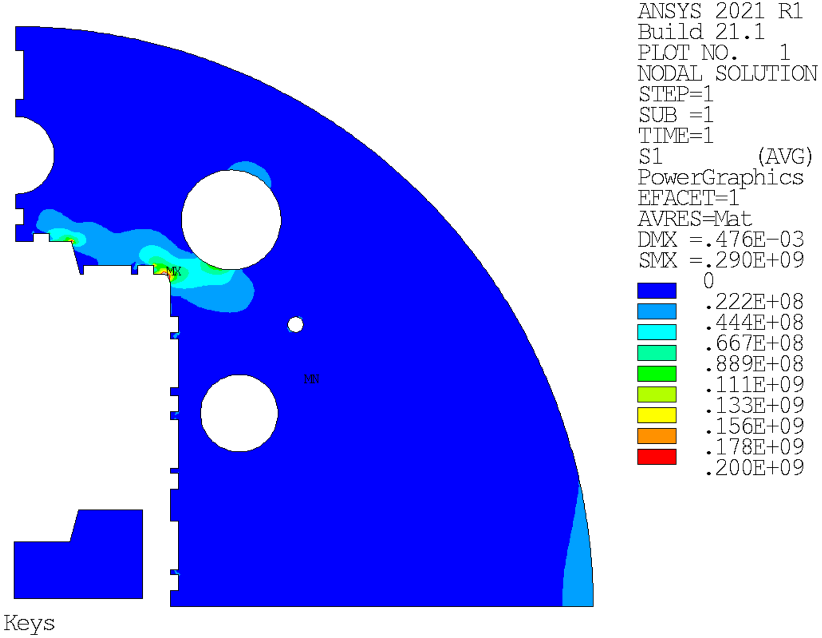
Hoop Stress

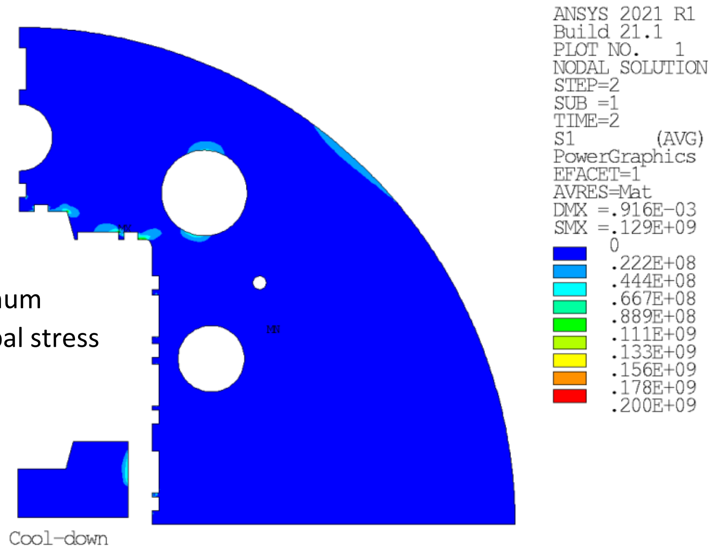


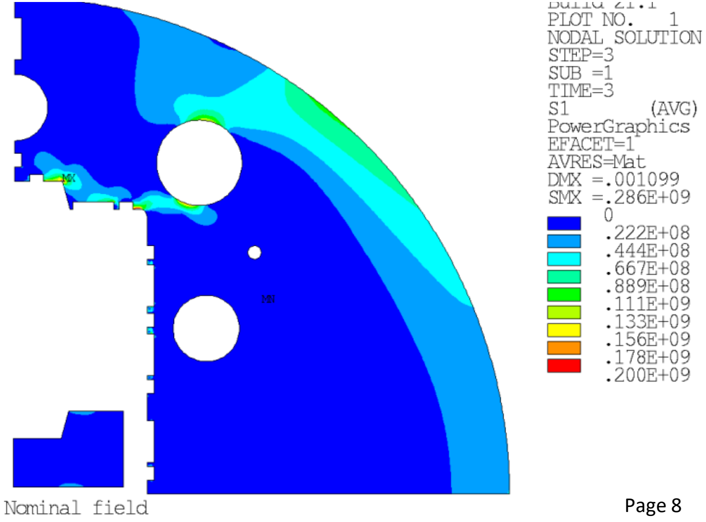
Nominal field

Mechanical Analysis

Maximum principal stress







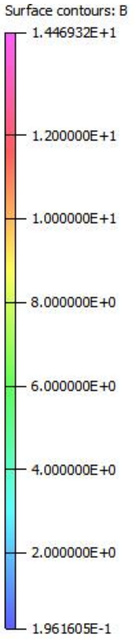
3D Magnetic Analysis – I_{op} = 14.77 kA

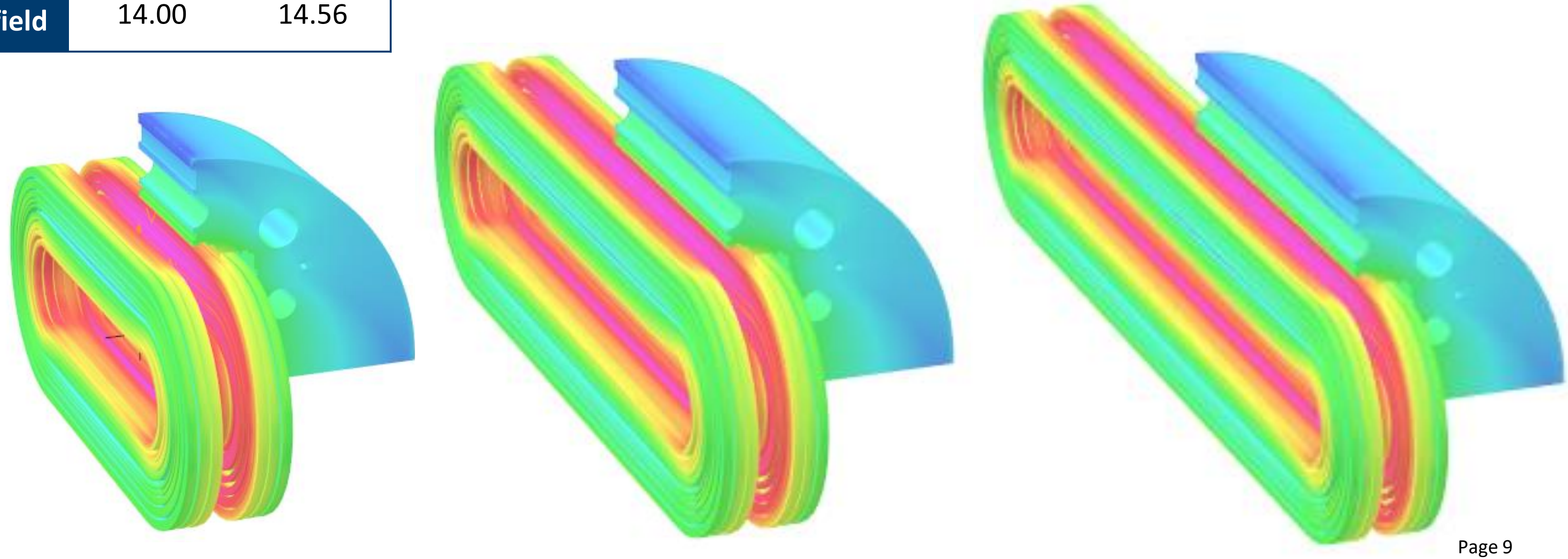
B_0 in T	B_p in T	L_{ss} in mm
13.81	14.47	500

B_0 in T	B_p in T	L_{ss} in mm
13.98	14.70	1000

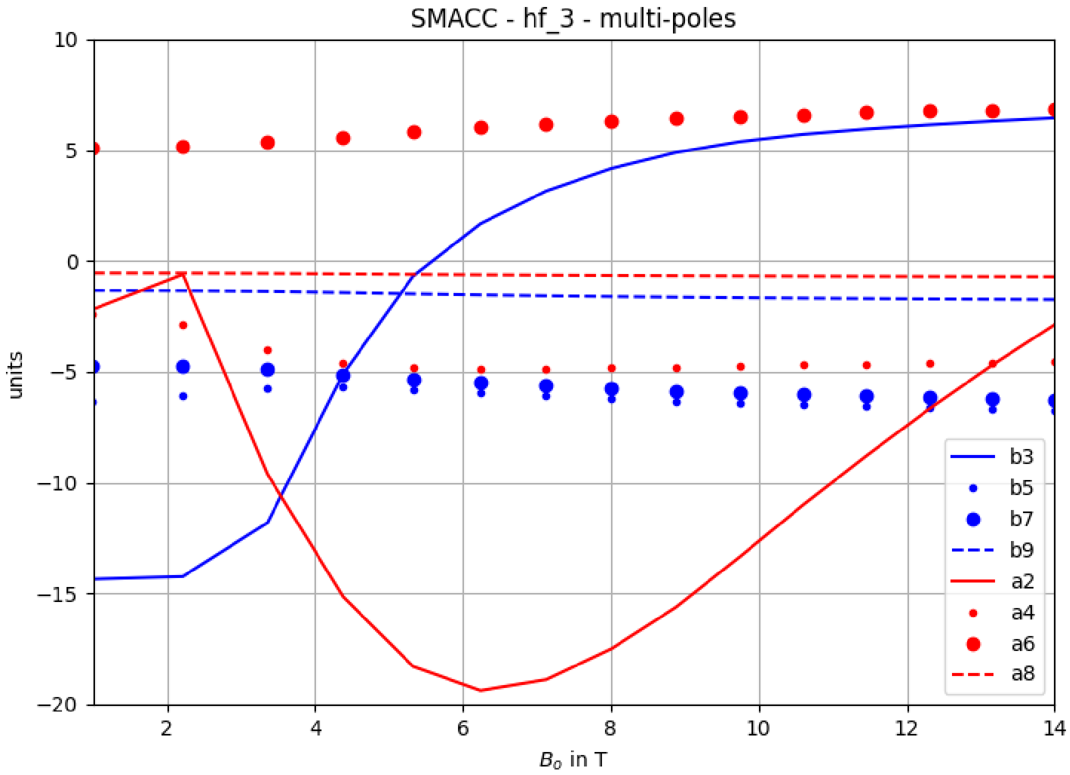
B_0 in T	B_p in T	L_{ss} in mm
14.01	14.71	1500

2D without self-field	B_0 in T	B_p in T
	14.00	14.56





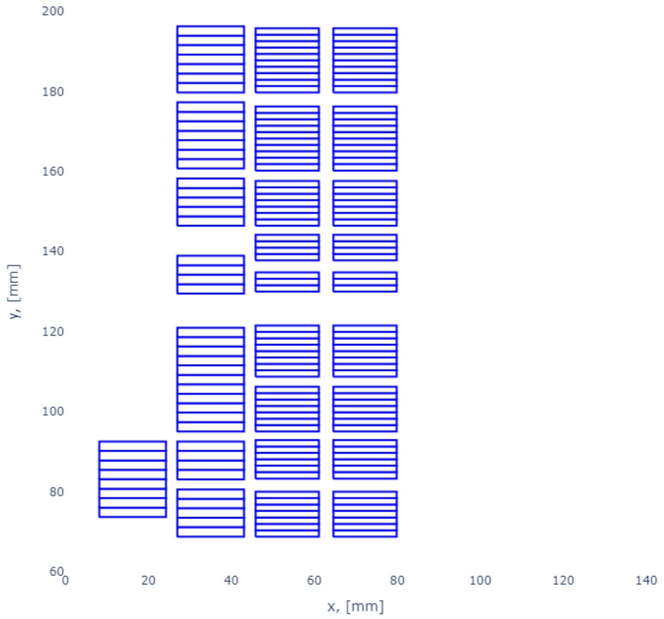
3D Magnetic Analysis – Multi-poles



2D

Multi poles	2D	L_{ss} = 500 mm	L_{ss} = 1000 mm	L_{ss} = 1500 mm
b3	+6.45	+5.84	+6.29	+6.36
b5	-6.75	-7.10	-6.94	-7.00
b7	-6.25	-6.45	-6.30	-6.38
b9	-1.75	-1.82	-1.72	-1.74
a2	-2.87	-16.95	-5.86	-4.58
a4	-4.55	-4.50	-4.39	-4.40
a6	+6.85	+6.91	+6.82	+6.83
a8	-0.71	-0.73	-0.76	-0.82
		-14.08	-2.99	-1.71

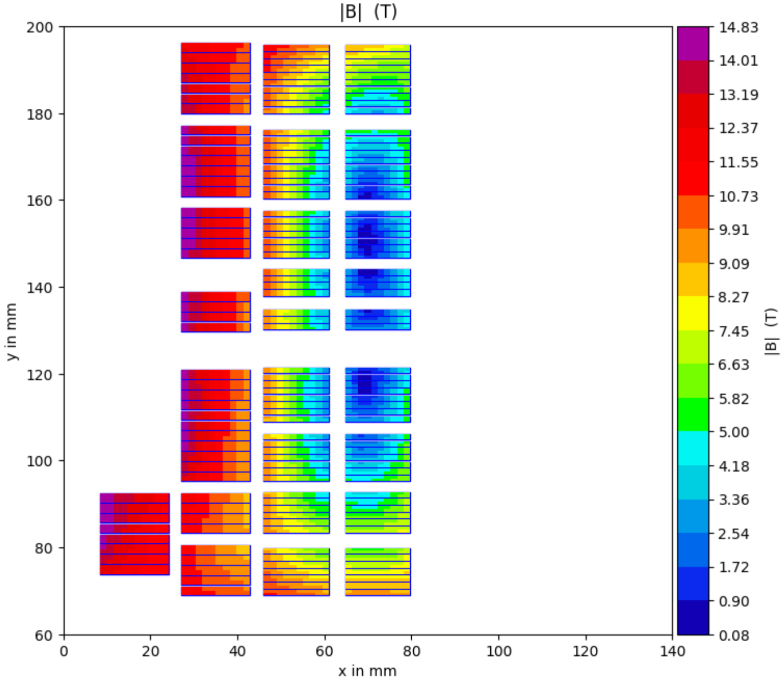
SMAAC 14 T and 13 T @ 4.5 K 9.5 – 10% margin



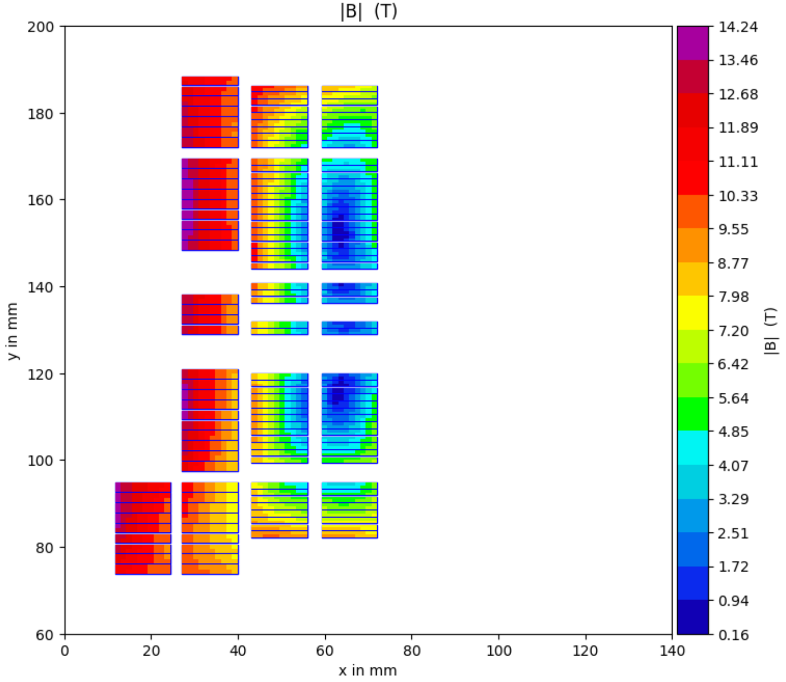
SMACC HF 3

SMACC LF 2

SMAAC 14 T and 13 T @ 4.5 K 9.5 – 10% margin

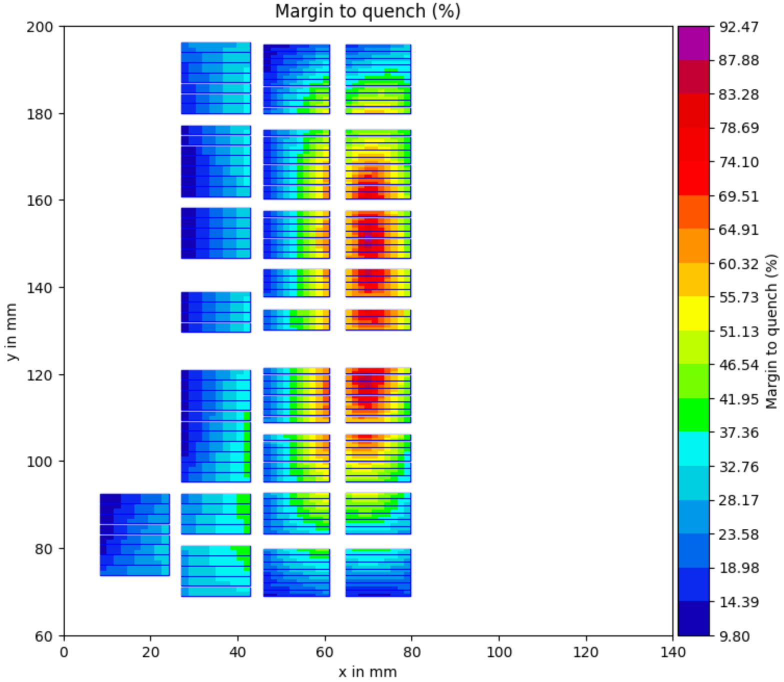


SMACC HF 3

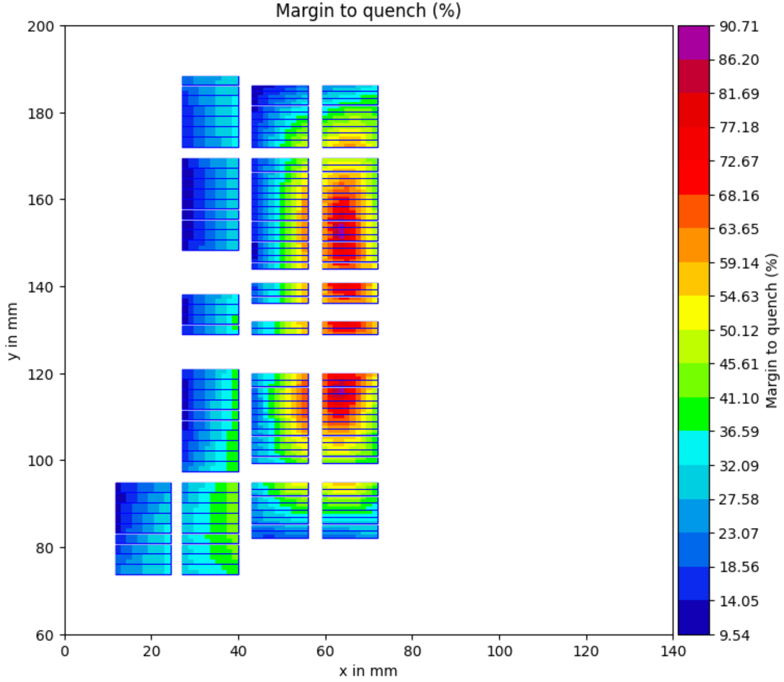


SMACC LF 2

SMAAC 14 T and 13 T @ 4.5 K 9.5 – 9.8% margin

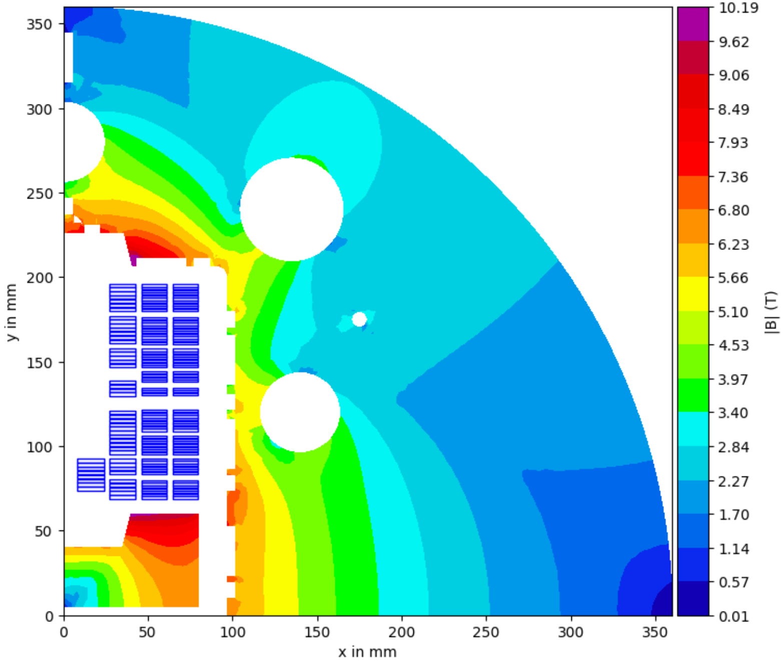


SMACC HF 3

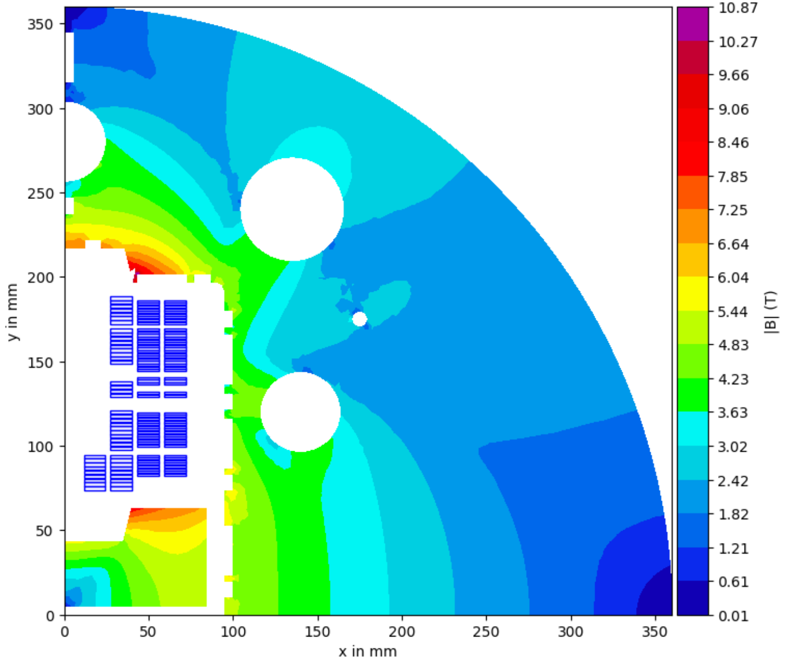


SMACC LF 2

SMAAC 14 T and 13 T @ 4.5 K 9.5 – 10% margin



SMACC HF 3



SMACC LF 2

Re-use shell, rods, bladders, keys

re-machine yoke

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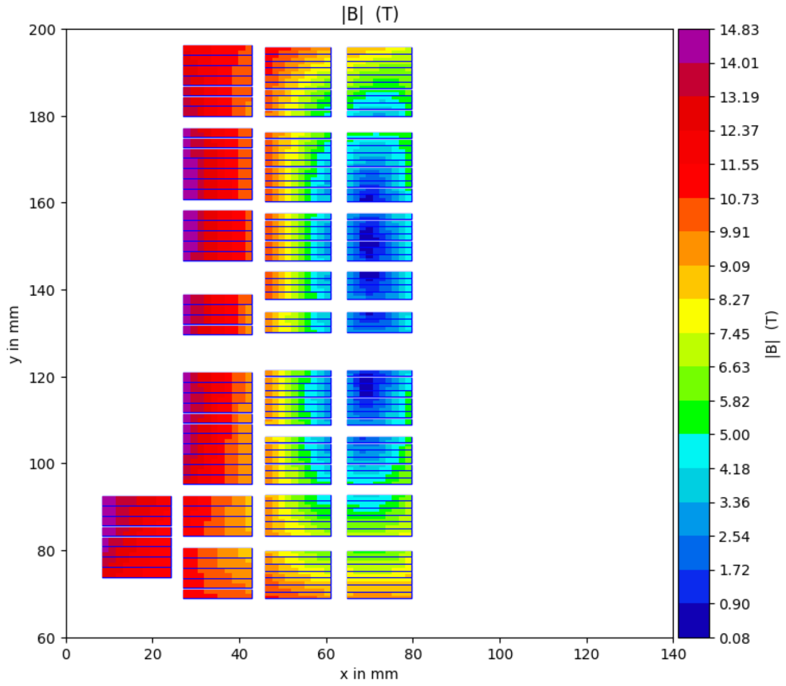
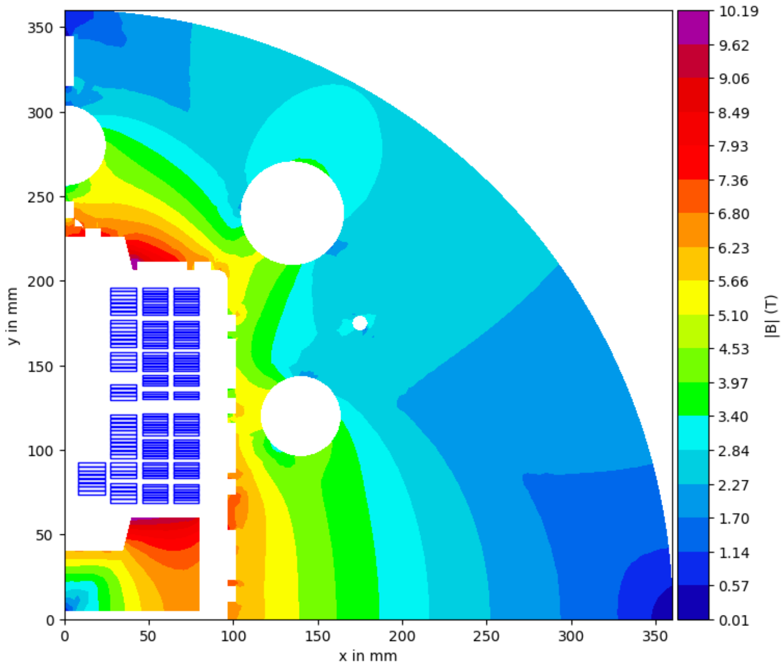
Stress-Managed Asymmetric Common-Coils (SMACC) –Nb_3Sn – hf_3 - 14 T

Ribs and spar thickness were optimized for mechanics.





|B| including self-field

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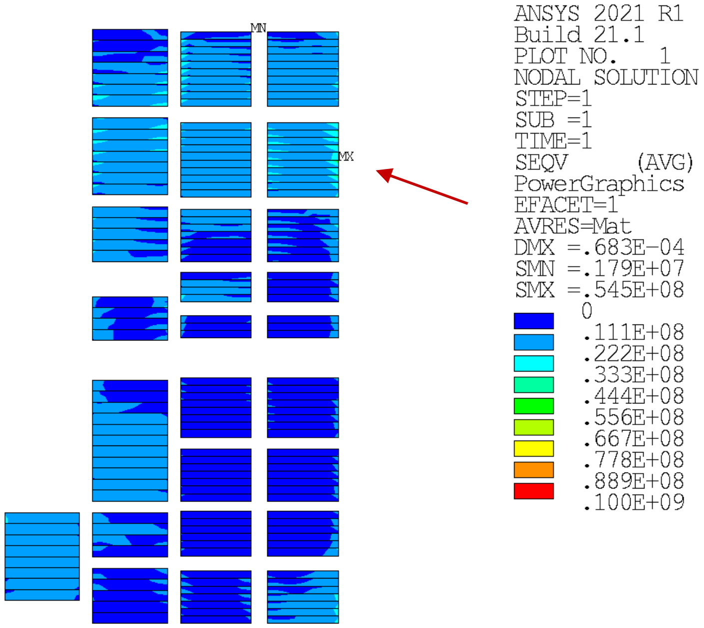
Mechanical Analysis

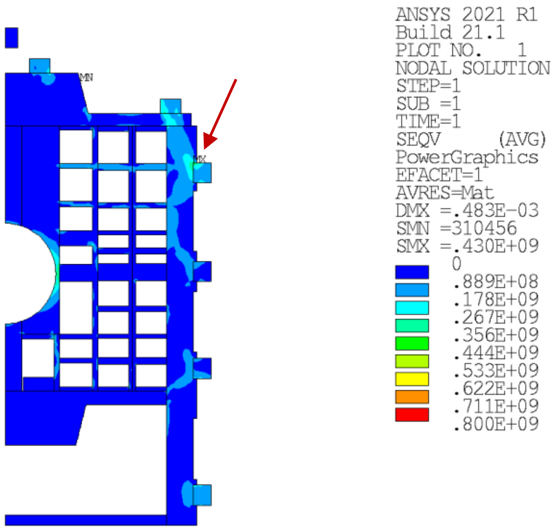
Von-Mises

Pre-load with 0.5 mm interference on the keys.

Von-Mises

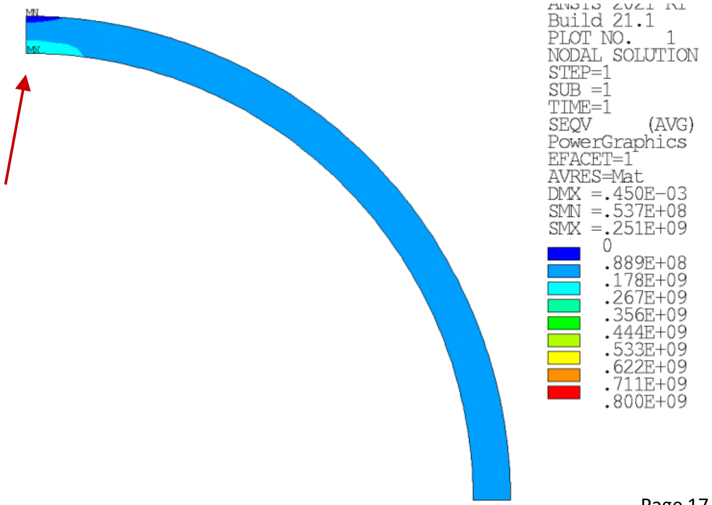


Keys



Keys

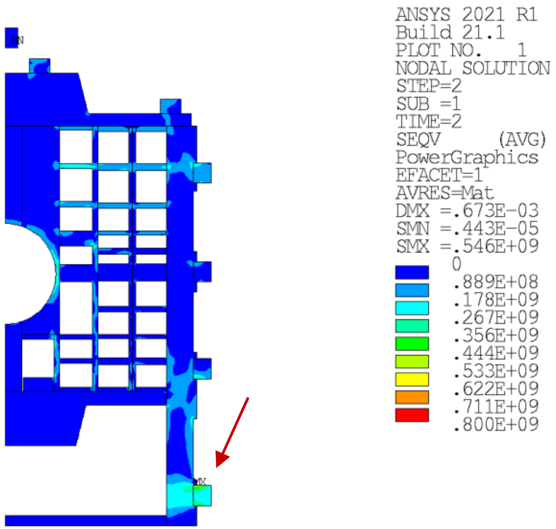
Hoop Stress



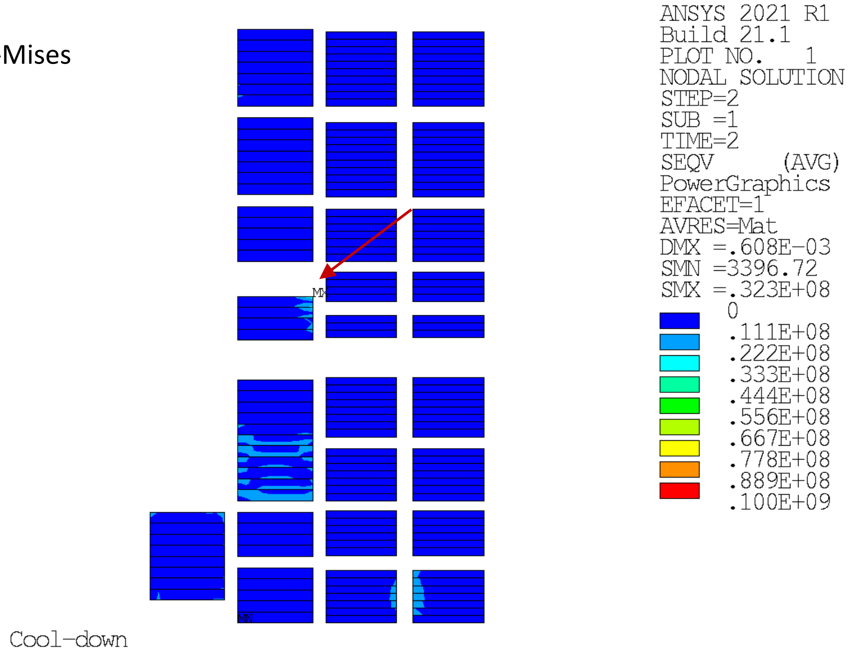
Keys

Mechanical Analysis

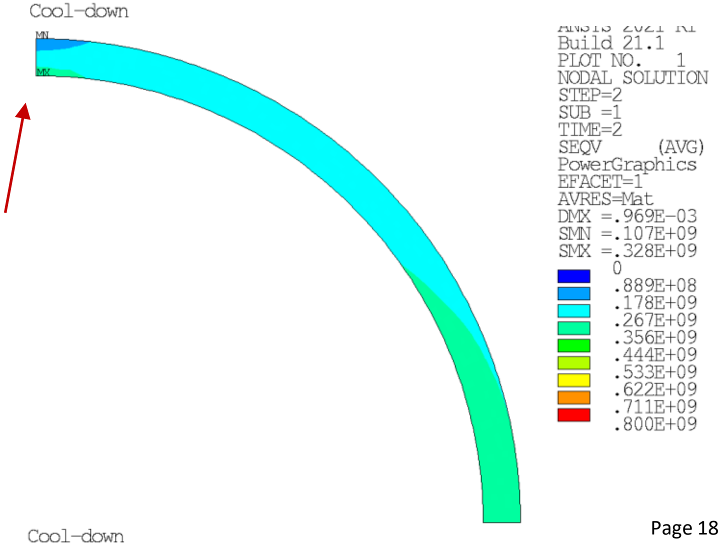
Von-Mises



Von-Mises



Hoop Stress



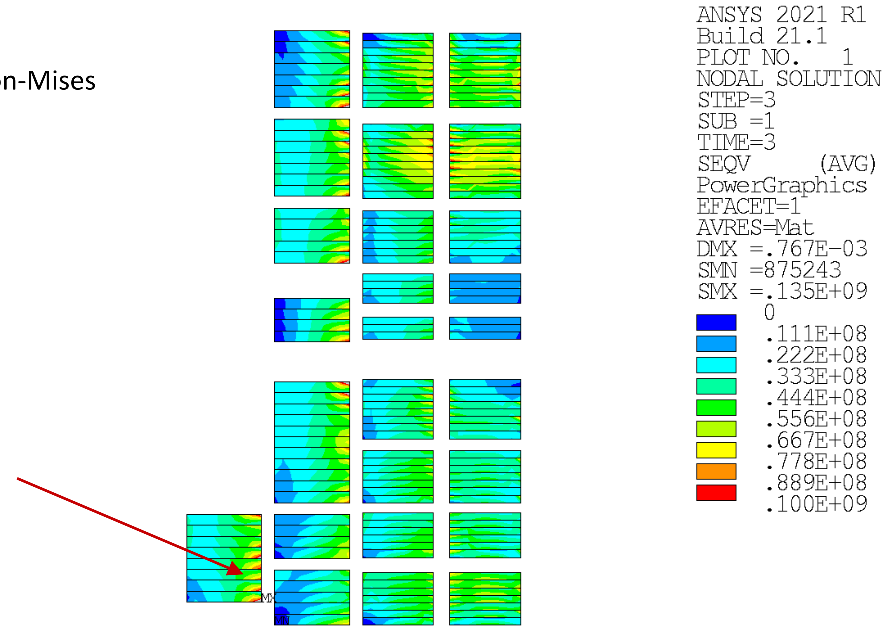
Mechanical Analysis

14 T operation

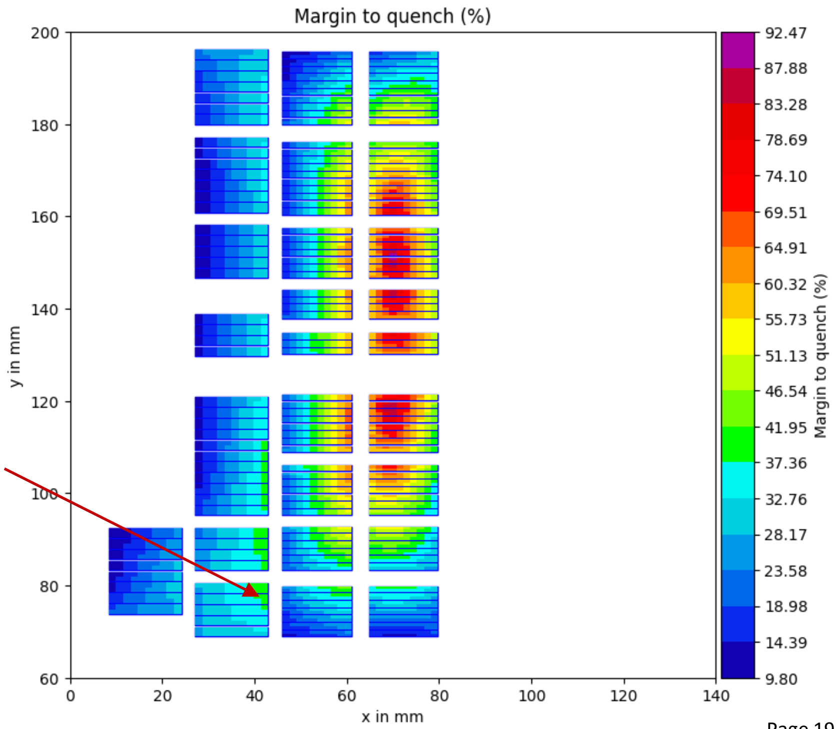
Stress on coils: 135 MPa on corners, other else < 100 MPa

> 30% engineering margin on the peak of stress regions.

Von-Mises



Nominal field

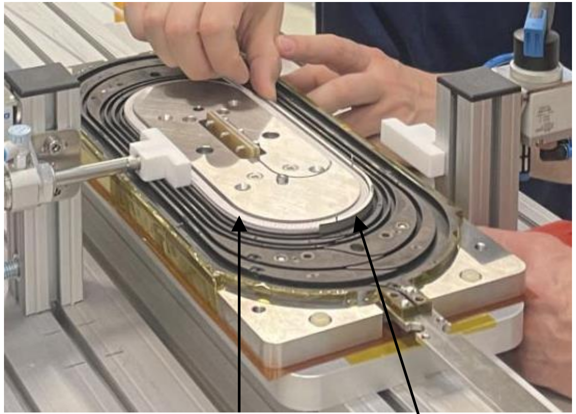


Subscale – Winding

spool

former

Rotating beam



After 1st coil block

rib

Before pushing down

After pushing down

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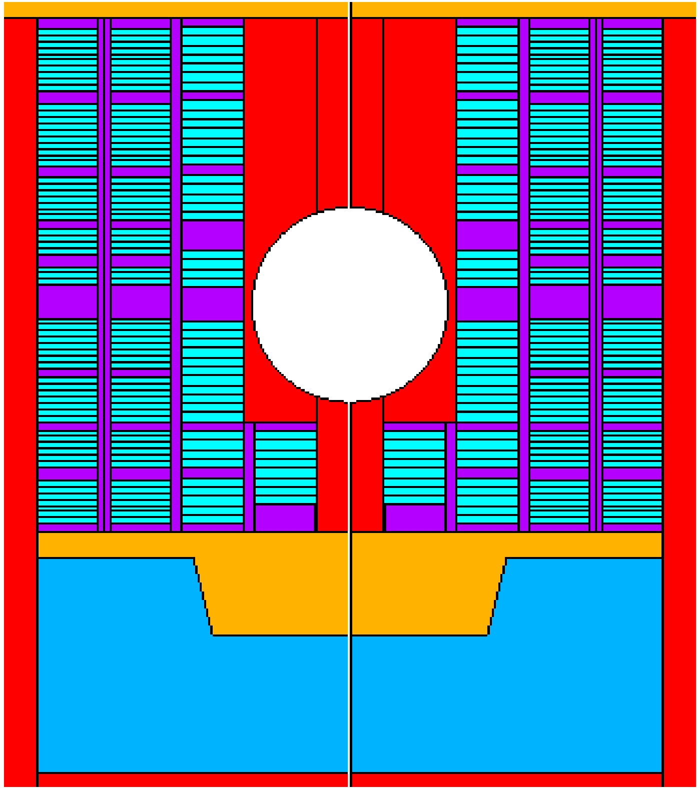
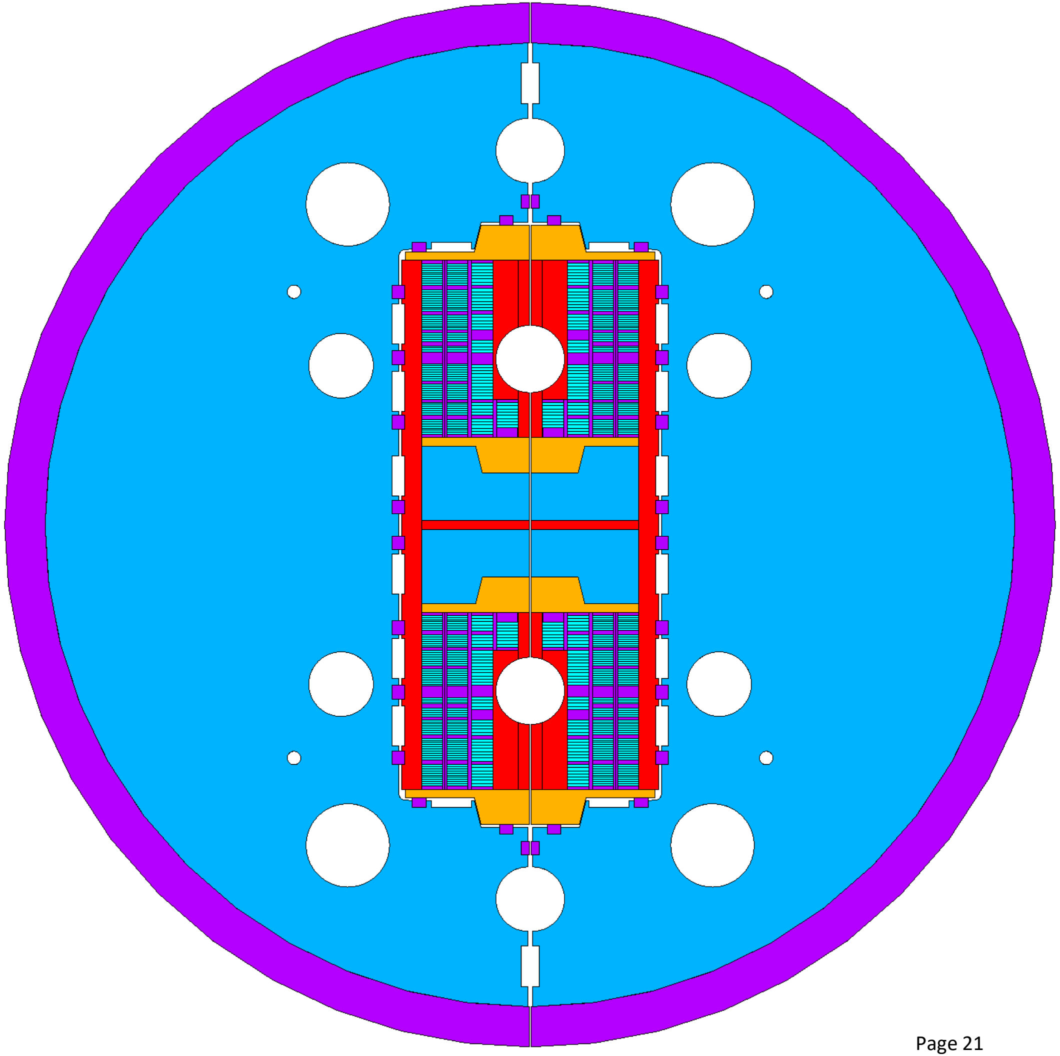
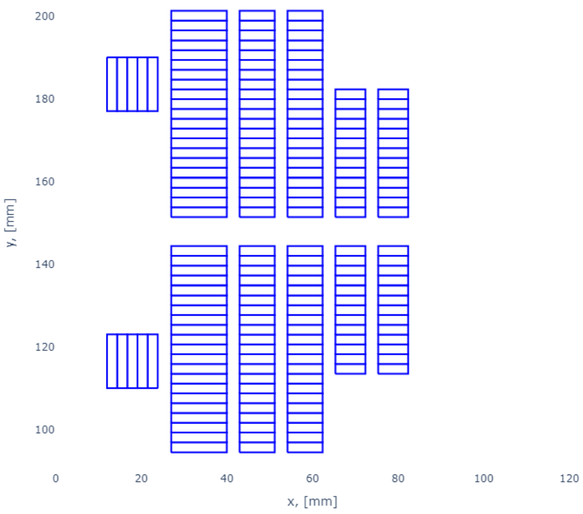




Magnetic Design

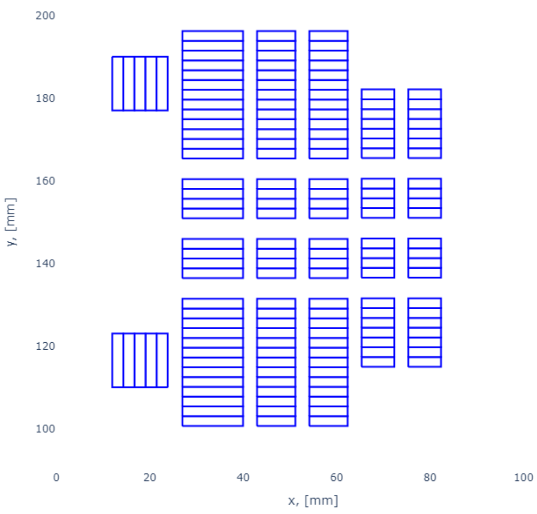
Let’s consider two typical common-coils turns distribution, with racetracks on the top and bottom of apertures for field quality correction (a and b). C shows a third design without racetracks / clover-leaf coils, with an additional common-coil on the hard-way bend direction.

a: racetracks / clover-leaf coils and wide blocks



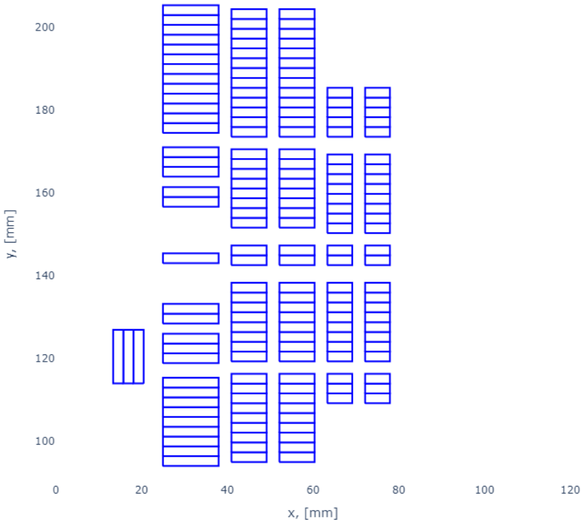
Stress-management with spars, but high vertical load

b: racetracks / clover-leaf coils and thin blocks



Stress-management with spars and ribs

c: only common-coils and thin blocks



Asymmetric design